# A Simple Digital Imaging Method for Dirt Detection on Eggshells

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**Abstract.** The objective of this research was to develop an off-line vision system to detect defective eggshells, *i.e.*, with dirty eggshell, by employing a classification algorithm based on a few logical operations, allowing a further implementation in an on-line grading process. In particular, this work was focused to study the feasibility of identifying and differentiating dirt stains on brown eggshells caused by organic residuals, from natural stains, caused by deposits of pigments. Digital images were acquired from 384 clean and dirty brown eggshells by employing a CCD camera endowed with 15 monochromatic filters (440-940 nm). Each dirty eggshell presented only one kind of defect, i.e., blood stains, feathers and white, clear or dark faces, while clean eggshells did not present organic residuals or evidences of feather, but their external color was characterized by clear or dark natural stains. A MatLab® devoted code was developed in order to classify samples as clean or dirty. The program was constituted by three major steps: first, the research of an opportune combination of monochromatic images in order to isolate the eggshell from the background; second, the detection of the dirt stains; third, the classification of the images samples into the dirty or clean group. The proposed classification algorithm was able to correctly classify near 93% of the samples. The robustness of the proposed classification was observed applying an external validation to a second set of samples, obtaining similar percentage of correctly classified samples (92%).

**Keywords.** *Brown eggs, eggshell defect, vision system, multispectral image, image analysis*.

## Introduction

In the poultry industry the early separation of dirty and cracked eggs from qualified ones is a fundamental issue to be achieved for both economical and sanitary reasons: when assigning a quality designation to an individual egg, freedom from stains and foreign material are considered (United States Department of Agriculture, 2000). Regarding the food safety, different types of harmful bacteria could be deposited along with dirt on the outside of an egg and they could penetrate into the shell (Garcia-Alegre et al., 2000). In Europe, market regulations do not allow any egg washing process, and the processing of poultry eggs has three steps: collecting, grading and packaging (García-Alegre et al., 1997). While collection and packaging have been largely automated, the eggs grading step, in which eggs are inspected for defects detection, is still done manually. Automation of the grading process could help control costs, reduce the work load on graders and improve the quality of the control process. Due to the subjective nature of the egg grading process, the use of artificial intelligence techniques in the automation process could be attractive. The principal objective of this research was to study the feasibility of identifying and differentiating dirt stains on brown eggshells caused by organic residuals, from natural stains, caused by deposits of pigments, by applying a multispectral vision system and by employing a classification algorithm based on a few logical operations able to present results that could be easily interpreted.

## Materials

### *Eggs sample*

During the analysis a total of 384 eggs were evaluated. Samples were classified into two groups: *dirty*, whose eggshell presented organic residuals on the external surface, i.e., blood stains, feathers and white, clear or dark feces, and *clean*, including eggs whose shell was free of adhering dirt or foreign material and was not cracked or broken (Fig. 1). In this work, 206 eggs (*clean*: n = 79, *dirty*: n = 127) were employed as training set (*Set 1*) and 178 (*clean*: n = 69, *dirty*: n = 109) as validation set (*Set 2*).

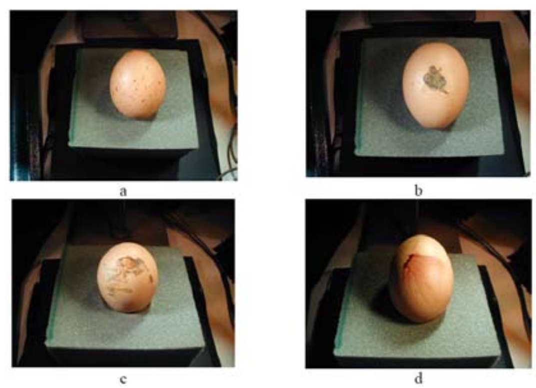


Fig. 1 – External characteristics of the studied eggshells: a) clean eggshell with dark 2 natural stains; b) eggshell with dark feces; c) eggshell with clear feces; d) eggshell with 3 blood stains.

### *Vision system*

The vision system used during the analysis consisted of a CCD monochromatic camera, equipped with a Nikon AF lens manually regulated. The camera was endowed with 15 monochromatic filters that let the camera acquire images in the optical range from 440 nm to 940 nm. The resolution of the camera was 480×640 pixels. A hemispheric chamber with black walls was put around the vision test station, in order to create a uniform light field around the object and to eliminate any effect of environmental light. The light source was provided by four incandescent lamps, attached at equidistant points on the inside of the chamber. The images were acquired using a black background. Every image utilized a white standard to ensure that the intensities of all images were of a consistent scale.

## Methods

Digital images of dirty and clean samples were acquired using the described off-line vision system. Although the system worked off-line, with the aim to adapt the system to an on-line grading machine, to detect and sort out contaminated samples while progressing on the mechanized conveyor belts, two images (of two opposite sides) were acquired for each sample and for each wavelength. The images acquired by the camera were processed off-line with software application based in MatLab® (MathWorks, Inc., USA), developed in order to automatically identify samples with organic residuals. This program was constituted by three major steps: first, the isolation of the eggshell from the background by employing an opportune combination of monochromatic images; second, the detection of the organic residuals; third, the classification of the images of the samples as clean or dirty.

# Results

## *Isolation of the ROI*

Several tests have been performed focused to search for an appropriate combination of digital images in order to isolate eggs (the *region of interest*, ROI) from the background. All tests confirmed that the extraction of the blue channel (B, 480 nm) from the red one (R, 700 nm) allowed to obtain an image with a high discrepancy in gray values of the egg and the background. After calculating R-B images for each sample, these images were converted to binary ones (BW) through Otsu method. This generated images wherein white pixels (value = 1) represented the egg surface, and black pixels (value = 0) the background and the possible dirt stains. In the case of *clean* samples, also the pixels corresponding both to dark and clear natural were white. A morphological operation was performed on the BW images allowed filling black holes in the white egg corresponding to possible dirt stains. These images, showing the complete egg as a white particle in a black background, was considered as an “image mask” and, from this point on, was used to define the ROI for the rest of the processing program.

## *Dirt stains detection*

An element-by-element comparison was performed between ROI and BW images, in order to obtain a *dirt stains* image (DS) in which the pixels coinciding with the pixels of the image mask with value 0 and 1 were set to 0, while the pixels coinciding with the pixels of the BW image with value 0 (dirt stain) were set to 1. The aim was that the dirt stains appeared as white particles in a black background. In the case of clean samples, the entire DS image was set to 0, since the image mask and the BW one were alike, apart from some active pixels located above all in correspondence of the edge of the eggshell. These active pixels resulted from the morphological operation previously applied to the BW images and did not correspond to dirt stains. For this reason they were named “virtual stains”. Since these virtual stains were generated by the morphological operation applied to the BW images, they were found in DS images of both clean and dirt samples.

## *Labelling*

Through a labelling process, connected elements were found in each DS images and each of these structures was considered as a single object. In case of clean samples, the objects identified by the system corresponded to the cited virtual stains, and were always found in correspondence of the edge of the eggshell. Otherwise, in dirty samples, the objects identified by the system corresponded both to organic residuals effectively present on the shell and to virtual stains generated by the previously image processing. Each object was identified by a label and the corresponding area in pixels was calculated. In this way it was possible to obtain the total extension of both the virtual and dirt stains. For each image of clean samples, the maximum of the area ($a$) of the virtual stains was calculated ($a_{max}$).

By calculating the average value of $a_{am}$ ($a_m$ = 16 pixels) and the corresponding standard deviation ($\sigma_{am}$ = 4), the value of the range $a_{am}$+ $\sigma_{am}$ was considered as a threshold to discern dirt samples from clean ones. By removing all objects with *a* < 20 pixels, all the pixels of the DS images of clean samples were set to 0 (DS was completely black), while in the DS images of dirt samples only the pixels corresponding to the organic residuals were activated (gray level = 1). This means that all the samples whose DS image presented active pixels with an area value > 20 pixels were included into the *dirty* group. On the contrary, all the samples that presented in the DS image an area of active pixels < 20 pixels were considered *clean*. Fig. 2 reports the entire image processing describe in this work.

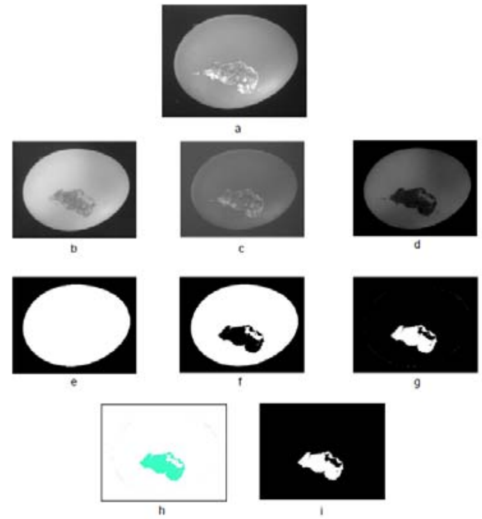

Fig. 2 – Image processing applied to a dirty eggshell with clear feces in order to detect 2 dirt stains: a), b), c) monochromatic images acquired at 560, 700 and 460 nm; d) R-B 3 image; e) R-B binary image (BW); f) image mask (ROI); g) DS image; h)image 4 resulting from the labeling process; i) DS image after removing objects with area < 20 5 pixels.

### *Internal and external validation*

All the clean samples and those presenting blood, white, clear and dark feces were correctly classified by the system. Regarding eggshell with feathers on the surface, the proposed classification procedure was able to correctly classify 90% of the sample, resulting in an overall accuracy of 98%. After applying the described image processing on the *Set* 2 samples, the corresponding images were classified on the basis of the proposed classification. Also in this case the system was able to correctly classify all the samples with an overall accuracy of 97%.

## Conclusions

In the present work a digital imaging method to recognize dirty eggshells from clean ones was presented. The method utilized an opportune combinations of red (700 nm) and blue (450 nm) digital images, which turn out to contain enough information for the proposed method to classify samples images as dirty or clean. On the basis of internal classification results, the proposed algorithm was able to correctly classify near 98% of the samples. The robustness of the classification procedure was observed applying an external validation (97% of samples correctly classified). All these results confirmed the great potential of the proposed method that was based on simple logical operations, whereas complex image processing techniques were described in the literature. Although the system worked off-line, it was programmed to acquire two images for each sample, in order to reproduce the working condition of an on-line grading machine. For this reason it could be considerate as a first step toward a further implementation in an on-line grading process.

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